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ABSTRACT

Hypertext is well-suited for educational applications where open learning and knowledge exploration is desired. In such applications, principles of good hypertext interface design should be employed to avoid navigational problems so as to maximize learning. Interface design, however, may also directly enhance acquisition of a particular knowledge structure. An interface that is based upon an expert's structural knowledge map may assist novice learners in developing a more sophisticated knowledge structure more closely resembling that of an expert. Pathfinder networks have been used successfully to differentiate expert and novice knowledge structures. The procedures described in this paper were used to design a structured interface for use in a research study currently in progress. Two microcomputer programs were used to develop the interface: The Knowledge Network Orientation Tool (KNOT) was used to create the pathfinder network, and Asymetrix Toolbook for the hypertext application. (Contains 19 references.) (Author/JLB)

Title:

Hypertext Interface Design and Structural Knowledge Acquisition

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Abstract

Hypertext is well-suited for educational applications where open learning and knowledge exploration is desired. In such applications, principles of good hypertext interface design should be employed to avoid navigational problems so as to maximize learning. Interface design, however, may also directly enhance acquisition of a particular knowledge structure. An interface that is based upon an expert's structural knowledge map may assist novice learners in developing a more sophisticated knowledge structure more closely resembling that of an expert. Pathfinder networks have been used successfully to differentiate expert and novice knowledge structures. The procedures described in this paper were used to design a structured interface for use in a research study currently in progress. Two microcomputer programs were used to develop the interface; The Knowledge Network Orientation Tool (KNOT) to create the pathfinder network, and Asymetrix Toolbook for the hypertext application.

Introduction

Inherent within knowledge is a network structure, or schemata, comprised of nodes (schema) and ordered, labeled relations connecting the nodes. Learning occurs when new information is integrated into these schemata through activation. Due to the limited capacity of working memory, most network nodes will be inactive at any given time (Anderson, 1983). Through the spread of activation, inactive nodes become active in working memory as new material provides a stimulus. As nodes are activated, they are marked so a path can be retraced to the starting node. Collins and Loftus (1975) claim that the activation of nodes in the network decreases proportionate to the strength of the links, introducing the idea of semantic similarity into the network. Learners generate elaborations for new information being learned (Haviland & Clark, 1974). Elaboration assists in subsequent retrieval of information, which is structured semantically. The generation and modification of knowledge structures stored as mental schema is a critical component of learning (Rumelhart & Ortony, 1977).

Hypertext computer systems are similar to the model of memory described above in that they store non-linear, interrelated units of information associated by links. While learners benefit from the ability to approach a domain from a variety of perspectives in hypertext, a persistent problem of hypertext systems is that of navigation. When too many choices are available, users have a tendency to become "lost" within the network (Conklin, 1987). Hypertext interface design should attempt to minimize this problem. It has been suggested that effective human-computer interaction depends in part upon communicating system structure and organization to users through the interface (McDonald, Dearholt, Paap. & Schvaneveldt, 1986; McDonald & Schvaneveldt, 1988). The authors cited above assume users will develop conceptual models of a system that can be characterized as schemata. By providing an explicit structure in the interface that is based upon a structural representation of the domain, users will develop conceptual system models that reflect characteristics of the domain being studied (McDonald, Paap, & McDonald, 1990).

Structural Knowledge

Although research has suggested that graphical browsers in general do not facilitate the acquisition of an expert's knowledge structure by novices (Jonassen & Wang, 1992), we anticipate that by using a specific type of graphical browser, learners may modify their pre-existing schemas (through activation and elaboration) differently than if an alternative type of browser were used. By using a pathfinder network as the browser, learners may develop schemas that are more consistent with that of an expert. The conceptual model that hypertext users develop is a mediating type of knowledge termed structural knowledge. Designing a hypertext interface after an experts knowledge structure as represented by a Pathfinder network may help users to develop a more effective user model, assisting learners in acquiring higher-order procedural knowledge.

Defining Structural Knowledge

The distinction between declarative and procedural ways of knowing is common in cognitive psychology (Ryle, 1949; Gagn_, Yekovich, & Yekovich, 1993; Jonassen, Beissner & Yacci, 1993). Structural knowledge is an intermediate knowledge between descriptive and procedural knowledge. Structural knowledge describes how declarative knowledge is

interrelated. In addition to knowing that, learners need to know why in order to know how. Thus, structural knowledge mediates the translation of from declarative knowledge to procedural knowledge by showing how declarative knowledge is interconnected (Jonassen, Beissner, & Yacci, 1993). Structural knowledge is essential to the development and use of higher order procedural knowledge applied within any content domain.

Structural Differences between Experts and Novices

Research has suggested that experts understand at a deeper, more abstract level than do novices (Chi, Feltovich, & Glaser, 1981). In addition, experts have a difficult time verbalizing their knowledge, since much of their knowledge has become automatic (Cooke, 1990). Further, experts and novices differ in the facts and rules in memory, as well as how those facts and rules are organized in memory (Chi, Feltovich, & Glaser, 1981; Murphy & Wright, 1984). Experts possess a different knowledge structure than novices, and know when and why specific facts or rules should be applied to specific cases. Although representing expert knowledge is of particular interest to expert systems research, other computer-based instructional models such as hypertext systems may benefit from explicitly providing novices with an explicit expert knowledge structure.

The Relationship Between Structural Knowledge and Hypertext Interface Design

The knowledge representation and acquisition models discussed above have implications for hypertext-based instruction. The limited capacity of working memory restricts learning. Formal learning usually consists of information presented in a sequential fashion, either through verbal or textual presentation. A learner therefore must break down sequential material into manageable chunks that can be transferred from working memory to long-term memory In addition, the goal of learning is the tuning and refining of one's mental knowledge structure. This means that a learner must add chunks of information in working memory to long-term memory by integrating these chunks into pre-existing schemata through spreading activation. As noted above, experts have well-developed mental schemata that differ from those of novices. We anticipate that novices may benefit from hypertext-based instruction that incorporates an expert's knowledge structure for two reasons. First a useful conceptual model for the hypertext system is provided for the user. Second, an explicit cognitive structure of knowledge domain becomes a component in the spreading activation process. If a link can be made between the user model and representation of the domain, novice learners should benefit from incorporating an expert's knowledge structure into a hypertext user interface.

Assessing Structural Knowledge: Pathfinder Networks

A variety of techniques for analyzing and representing structural knowledge have been identified (Jonassen, Beissner, & Yacci, 1993). We selected Pathfinder networks as our technique.

Pathfinder Associative Networks

Pathfinder associative networks (PFNets) are configurations in which concepts are represented in a node-link-node format. The network is constructed from proximity ratings of all possible pairs of semantic terms. Each link between PFNet nodes is assigned a value representing the strength of the relationship. The links can be directed or undirected, and are calculated based upon the minimum distance between concepts. A link is constructed if

the distance between concepts is greater for every possible path than for the paired terms. PFNets are similar to MDS networks, except that PFNets do not require ratio assumptions about the proximity data, and are not bound by the hierarchical constraints in most other clustering techniques (Dearholt & Schvaneveldt, 1990).

Using the Knowledge Network Organizing Tool

The Knowledge Orientation Network Tool (KNOT) is a series of computer programs available on multiple hardware platforms for constructing, analyzing, and assessing pathfinder networks. The program uses an algorithm that analyzes a proximity data file created by semantically differentiating all possible pairs of selected concepts or terms. The examples that follow are part of a research study being conducted by one of the authors of this paper. For that study, the KNOT microcomputer program was used in conjunction with Asymetrix Toolbook as a relatively inexpensive and readily available means of providing an explicit structure in the hypertext interface. Although the examples here use the Microsoft Windows environment on the IBM PC, the procedures demonstrated here can be applied to the Macintosh environment using the Macintosh version of KNOT and an authoring tool such as Hypercard.

Constructing expert and novice maps. Expert and novice maps are both constructed using the same procedures. A number of individual KNOT program modules are used to construct and analyze PFNets. The IBM PC version of the software contains both command line and graphical user interface (GUI) versions. The command line version was used in designing the structured interface discussed here. Constructing a PFNet requires at least three steps. First, the terms representing the domain must be defined. Second, the terms are stored in an ASCII text file entitled TERMS, for use with the RATE program. Third, the RATE program is used to semantically differentiate all possible pairs of terms.

Define the concepts that represent the domain. Proximity data is based upon the rater's differentiation of paired terms representing the content domain. In the design for this study, eighteen terms representing the major categories of moral philosophy were used.

Rate all possible pairs of terms. Ratings can be acquired by using the RATE module within KNOT, which will randomly present the rater with all possible pairs of terms. A proximity file is created after all pairs are rated. The RATE program uses a 9 point scale for differentiation., with the end points representing a high degree of similarity or dissimilarity. Instructions for individual raters and the direction of the ratings (whether 1 equals highly dissimilar or similar) can be specified and written to an ASCII file entitled INSTRUCT. For our study a single subject matter expert was consulted to rate the terms used to differentiate 18 concepts describing moral philosophy.

Use the Layout function to generate the pathfinder network. Once the proximity data file has been created, the LAYOUT program module within KNOT is used to construct a PFNet from the proximity data. Figure 1 shows the PFNet produced by the proximity data resulting from our rater's data. In this example the following parameters were used: q=-1, r=.

SEE FIGURE 1 APPENDIX D

Assessing differences between two or more PFNets

The similarity of two or more PFNets can be assessed using the NETSIM.EXE program. NETSIM generates a relatedness coefficient ranging from 0 (very dissimilar) to 1 (identical). NETSIM can be used for comparing individual PFNets from a group of experts, comparing expert and novice PFNets, or for comparing PFNets from the same user generated before and after instruction. Although PFNets can be assessed visually for similarity, the NETSIM function will more accurately assess the differences between expert and novice networks.

Hypertext Interface Design and Knowledge Acquisition

Given the navigation problem users usually experience with hypertext, the structured interface under discussion was designed as a single Toolbook page with a recordfield for individual text nodes embedded on the background of the page. The 18 nodes comprising the PFNet act as buttons, which display the text window and textual information specific to each individual node.

The windowed interface

The text window is hidden from view until the user selects an option from the menu interface. Once selected, the text window containing information specific to each individual node fills approximately fifty percent of the screen. The interface remains visible behind the window. A scroll bar allows the user to view all the text within the window. In order to provide an explicit knowledge structure in the interface itself, the text window cannot be resized, and multiple windows cannot be opened simultaneously. Links between nodes are represented as "hot words" in the text, which are surrounded by a rectangular box. Users also have the option of closing the window to once again make the entire menu interface visible. Figure 2 shows an open window with the interface in the background.

SEE FIGURE 2 APPENDIX

Providing users with an explicit structure

Since users frequently returned to the interface map, the underlying knowledge structure was made explicit. As users interact with the system, the concepts of moral philosophy are learned within the context of the knowledge structure provided by the interface. Given the research and theory under girding Pathfinder networks, we predict that a learner's PFNet resulting from this interface will differ from a PFNet generated if a different interface (such as alphabetical listing of the terms) were used. Further research is needed to substantiate this assumption.

Designing a hypertext menu interface from a PFNet

Designing a hypertext menu interface with an authoring system such as Toolbook can be accomplished in a variety of ways. Once a list of terms are paired, the *.LO file can be displayed
on the screen using LAYOUT.EXE and sent to the printer. Consider the following design options:

Freehand drawing. Use the *.LO printout as a template and reproduce its main

features such as number and position of nodes links in Toolbook (or Hypercard) with as much accuracy as possible.

Cut and Paste. Configure your computer to run KNOT from within Windows (this is not recommended by Interlink). Once the *.LO file appears on the screen, reduce the screen to an active window (by using the ALT - ENTER keystroke). Take a "snapshot" of the window using the ALT - Print Screen keystroke. Minimize KNOT on the desktop, and paste the screen print into a draw or graphics application. Copy and Paste the image into Toolbook.

Optical scanning. Scan the *.LO printout to a file. Depending upon the file format used, an import filter that will allow the file to be imported directly into the active book may be available within Toolbook.

Conclusion

The advent of a number of microcomputer hypertext authoring systems allows designers to create a variety of instructional and supplemental materials. If knowledge acquisition is enhanced through the use of Pathfinder networks, we encourage their use in the interface design. The procedures described in this paper were used to design an instructional module to research the effectiveness of PFNets as a blueprint for interface design and the effects of such an interface upon the learner's post-treatment knowledge structure. Clearly, more research is needed to determine the potential uses of PFNets with hypertext systems. We have presented a design model for constructing a PFNet interface. We encourage readers to experiment using PFNets with hypertext in other domains.

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